Clad: Accurate Capture Of Transmission In Multi-Hop Wireless Networks

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Abstract

In wireless networks so far, multiple active flows and cooperative transmissions has not been yet considered. The case of VMISO links is considered here. To achieve this and to improve performance, cooperative transmission is used in multi-hop wireless networks. In the end, VMISO in physical layer benefits and improves network layer performance. After an investigation on this end result, we show that the improvements are non-trivial. A study is made on routing decisions and finally a Cluster Adaptive (ClAd) routing protocol is introduced. This protocol also strengthens Virtual Multiple Input Single Output (VMISO) links to achieve performance improvements. It also gives solutions to decision problems like the number of cooperating transmitters for each link and cooperation strategy used by the transmitters.

Keywords— *cooperative communication, VMISO, multi-hop wireless networks, routing protocol.*

1. Introduction

In networking, the nodes in a cluster communicate with each other in a co-operative and non-cooperative way. Here the focus is on cooperative communication in networks. Generally, more than one antenna is required at source part to transmit. Thus a single antenna can be used in a multi-user environment. This antenna is shared. Thus a virtual multiple antenna is generated at transmitter side. Single antenna mobiles take advantage of this communication. Due to sharing VMISO is obtained. Each node cooperate with each other to improve certain QoS. VMISO can broadcast easily to cooperating nodes with a single transmission. It improves transmission and thus improves communication performance.

The next section identifies the problems found out while using a single input and single output concept in wireless networks. We also illustrate the need of cooperative communication in wireless networks.

The following section identifies several related works and their corresponding advantages and disadvantages has also been listed out.

2. Basic Problems Identified

Several problems are identified in the previous works. It can be classified into two categories as shown below.

2.1 Single Input and Single Output

Single Input Single Output (SISO) Fig.1consists of a single antenna at the source side and a single antenna at the antenna at receiver side. Transmission through SISO path has been disadvantageous mainly because (in networking area) when a single transmitter node transmits signal to a single receiver node, the signal gets affected mainly because of interference. In SISO each link interferes with one another and end-to-end throughput decreases.

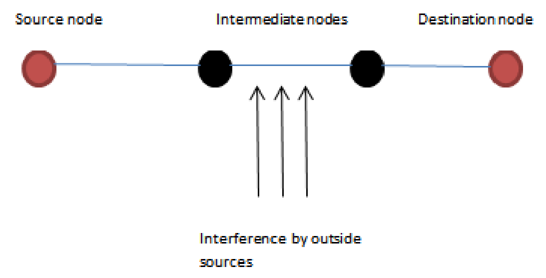

Fig.1. Illustration Of SISO Affected By Interference

2.2 VMISO without Cooperative Communication

VMISO is Virtual Multiple Input Single Output. Here there are a cluster of nodes at the receiver side Fig.2 . It has got better performance benefits than SISO and also since each node distributes flows, the rate increases but total time taken for each hop is now increased. Clusters are also found out to be fixed in size and also the lack of cooperation among nodes further sustains the interference problem in VMISO along with its benefits. Hence we bring up the concept of cooperative communication in VMISO.

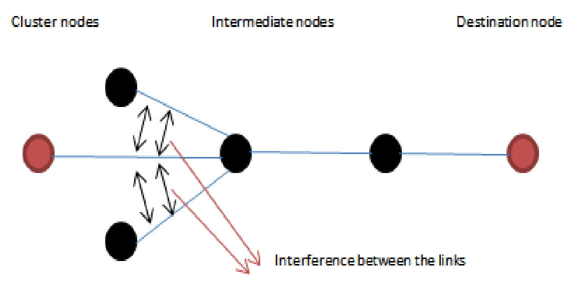

Fig.2. Illustration Of Interference In VMISO Links

None of the existing works considered routing in wireless networks with multiple active flows and cooperative transmissions. And also as the problems of SISO has been found out to be extreme in multi-hop networks, the introduction to VMISO has given far better results. Thus a further research on VMISO is done. Here, a better performance is achieved through cooperation among the cluster of nodes in order to attain cooperation gain and to improve rate and reduce interference. This is done with the help of an adaptive diversity routing protocol. This aims at joint optimization of links and thereby optimizing throughput as well as hop distance. The use of adaptive diversity algorithm dynamically adjusts the cluster size. That is, cluster of nodes at source would be able to adapt to changes in destination.

Bringing cooperation among the network nodes and giving tolerance to interference has been a challenge throughout this area. Cooperation also aims at attaining cooperation gain which includes bringing up power gain and diversity gain.

3. Related Works

Cooperation among mobile users in a wireless network can be exploited to induce diversity and rate gain, using distributed space-time coding method[1]. There are two schemes highlighted in this paper (i)Cooperative nodes and (ii)Non-cooperative nodes.

In cooperative nodes, they considered BER when SNR is high as well as in the case when SNR is low. In cooperative nodes the spatial diversity can be achieved if the errors are neglected. Minimum BER was obtained. Cooperation is done mainly for rate gain.

In the case of non - cooperative nodes, interference was high and also the nodes where not able to make out who send the data. There occurred decrease in rate and also rate loss. Its advantage is that it is able to minimise BER by reducing SNR. But it has the following disadvantages (i) For co-operation, resources should be allocated at source and destination or relay nodes, but there occurs rate loss due to exchange of information between source and destination.(ii)Here there occurs loss when cooperation diversity gain is made which increases later on.

Multilayer approach [2] uses antenna arrays in conjunction with space-time codes. It can significantly improve signal quality and thereby enhance the capacity of ad hoc networks. Depending on whether multiple transmitting antennas (inputs) and/or multiple receiving antennas (outputs) are used, one could have a Multi-Input Single-Output (MISO) system, a Single-Input Multi-Output (SIMO) system or a Multi-Input Multi-Output (MIMO) system[2]. The deployment of antenna arrays on small mobile nodes, however, is infeasible due to the required size of these antennas. Its advantages are : (i) It spans physical layer, MAC layer and routing layers. (ii) Significant improvement in end-to-end performance, throughput and delay. (iii)Robustness to mobility and link failures due to interference induced in links. (iv) Compared to SISO there was

150% end-to-end throughput increase and 75% decrease in end-to-end delay. (v) Increase in transmission range by increasing signal quality. (vi) Increasing robustness to link failures by selecting alternate route. But there are a few drawbacks found in this case (i)There was no mature higher layer protocols to translate the advantages of using cooperative diversity to enhance network performance. (ii)Fading is ignored in range calculations. (iii)Reduces data rate but increases delay.

Another protocol, Cooperative Source Routing (CSR) protocol [3] was used to convert physical layer gain into network level performance improvement [3]. With both route request and route reply control packets being transmitted cooperatively, CSR can explore routes with high cooperative diversity[3]. Advantages are : (i)There was no mature higher layer protocols to translate the advantages of using cooperative diversity to enhance network performance.(ii)Fading is ignored in range calculations. (iii)Reduces data rate but increases delay. (iv)Takes into account about path losses.(v)Total power increases. (vi)Number of retransmission of packets reduces. (vii)Boosts signal strength at receiver. (viii)Leads to lower packet corruption rate. And disadvantage is that the VMISO link cannot be established since there exits only insufficient number of neighbours to cooperate.

A set of iterative steps are involved. During the first iterative step, an upper bound on the objective value is obtained by solving a relaxed version of the MILP problem. The solution may become fractional. Therefore, a local search algorithm, called Feasible Solution Construction (FSC) [4], is proposed to obtain a feasible solution from the relaxed solution. The feasible solution obtained from FSC provides a lower bound on the objective value. Advantages are: (i) Increases capacity of wireless networks. (ii)Solve joint optimization problem of relay nodes and flow routing. (iii)Rate gain. (iv)Antenna systems with CC do not have to equip multiple antennas on each node in network and so each node has only a single antenna. (v)Spatial diversity is achieved. (vi)Higher throughput obtained. (vii)Lower transmission error. (viii)Capacity gain increased. And the following are the drawbacks : (i)Usage of orthogonal channel because only few users are transferring data simultaneously. (ii)Delay and time consuming in performing these operations.

In another work wireless cooperative multi-hop networks were considered, where nodes that have decoded the message at the previous hop cooperate in the transmission toward the next hop, realizing a distributed space-time coding scheme[5]. Objective is finding optimal co-operator selection policies for arbitrary topologies with links affected by path loss and multipath fading. To this end, the network behaviour through a suitable Markov chain were modelled and formulate the co-operator selection process as a stochastic shortest path problem (SSP) were formulated. Further, the complexity of the SSP through a novel pruning technique was reduced, starting from the original problem, and obtains a reduced Markov chain which is finally embedded into a solver based on Focused Real Time Dynamic Programming (FRTDP) [5]. The algorithm can find co-operator selection policies for large state spaces and has a bounded (and small) additional cost with respect to that of optimal solutions. Finally, for selected network topologies, results were shown which are relevant to the design of practical network protocols and discuss the impact of the set of nodes that are allowed to cooperate at each hop, the optimization criterion and the maximum number of cooperating nodes[5].

Its benefits are : (i) Optimal cooperator selection for links affected by path loss. (ii) Optimal cooperator selection for links affected by multipath fading. (iii) FEC is employed to improve transmission reliability. (iv)Error occurs during pruning is negligible. (v) Delay is decreases at each hop. But lacks in : (i)delay in small amount due to cooperator selection policy. (ii) SNR is kept minimum due to optimal selection of links. (iii)Effective network throughput decreases.

4. Cluster Adaptive Routing Method

An arbitrary topology is considered. There are cluster of nodes at sender and single node at the receiver. These cluster of nodes adapt itself to changes in the destination or receiving part and hence the name Cluster Adaptive (C*l*Ad) routing method. The steps involved in this method are :

- **Compute Path Information:**
  - ✓ give source and destination as inputs
  - ✓ find out shortest path
- **Compute Metric:**
  - ✓ Give shortest path as input.
  - ✓ Give modulation order as input.
  - ✓ Consider interference measure
  - ✓ Check whether end-to-end path is available.
  - ✓ Check if interference affects flow.
  - ✓ Cluster size is changed accordingly.

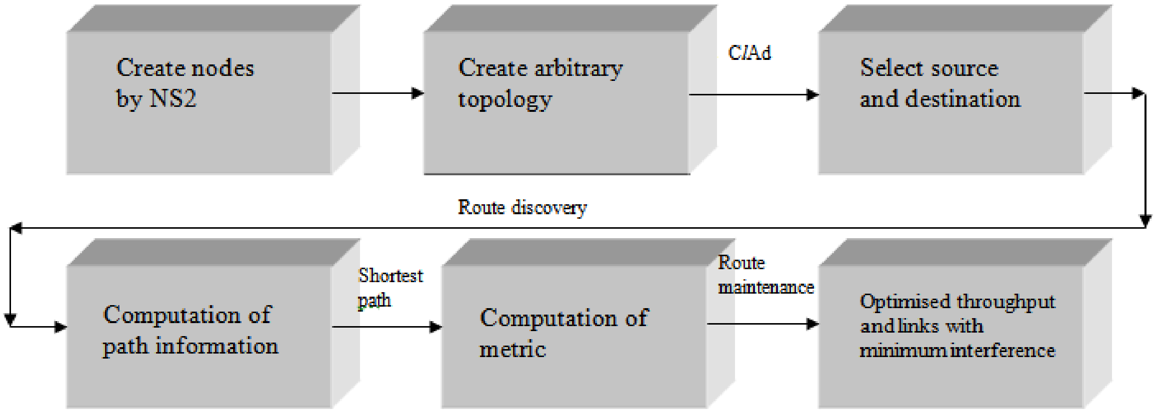

Fig.3 C*l*Ad Architecture

5. Cluster Adaptive Routing Protocol

Here we first focus only on the route discovery step of the routing protocol and use conventional route maintenance procedures for maintaining routes. Distance between source and destination is calculated by VMISO-range strategy[5]. Two main steps involved are:

- Route discovery
- Route maintenance

5.1 Route Request (RREQ)

RREQ is the first step in route discovery phase. It contains source node ids. It also contains ids of neighbours. It tells us about the active number of links. A pilot tone keeps track of number of links available in its area. Pilot tones are sent to all nodes in cluster at the source. When each node responses with a reply, a cooperation is achieved.

5.2 Route Response (RREP)

It computes interference power of each node. We will have an idea of the number of flows already served. Then we will get the number of hops in a path.

When the destination receives the route request, it transmits the Route Response (RREP) after adding the information about its vicinity[5]. Intermediate nodes forward the packet as usual, except that when any of their statistics has changed, they update it on the route response packet[7]. When the source receives the route response (RREP), it uses the statistics available on the packet to compute the metric. The source collects *l* paths received within a timeout duration .The source computes the path metric for each path for different values of n_c, m and selects the value that provides the best metric.

5.3 Route Failures And Maintenance

Finally route maintenance is done. When a route is failed, new route is recomputed. The overhead is kept minimum with the help of a wireless protocol ExOR (Extremely Opportunistic Routing protocol). It is a MAC protocol. After transmission ExOR chooses each packet route of a hop. It increases throughput, but does not use network capacity[6]. It also chooses the best sequence of nodes and forward each packet through that sequence.

6. Conclusion

The conclusion of this work is to improvise the cooperative transmission in multi-hop routing performance in wireless networks, in terms of better scalability and performance. The various protocols which were proposed before the Cluster Adaptive (C*l*Ad) routing protocol is to improvise metrics and reduce interference and also for joint optimisation of nodes.

Thus, the future work is focused on the enhancement on optimization of nodes, delay, energy, and packet delivery ratio will improve the mobility and energy efficiency in wireless networks.

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